

APPLICATION

OF

Jonathan M. Audy
Richard Redl
Gabor Reizik
Brian P. Erisman

FOR

UNITED STATES LETTERS PATENT

ON

DIGITAL BLANKING CIRCUIT

Docket No. A8SC1669US

Assigned to:

ANALOG DEVICES, INC.

DIGITAL BLANKING CIRCUITBACKGROUND OF THE INVENTIONField of the Invention

This invention relates to the field of blanking circuits, and particularly to blanking circuits for use
5 with digital input signals.

Description of the Related Art

Many electronic circuits provide digital signals to
10 following stages, which act in response to them. In some instances there can be noise on the digital signal; for example, the output of a comparator may contain noise if its inputs are noisy. This noise can cause unexpected and erratic behavior in a following stage that is switched by the comparator output.

When the digital signal is produced by a comparator, input-referred hysteresis is often employed to prevent noisy inputs from affecting the output. However, in the presence of a large amount of switching noise, the hysteresis needed may be so large as to significantly
15 affect the magnitude of the input voltage swings, and hence the overall circuit performance.

A circuit is needed that can prevent noise found in a digital signal from being propagated to a following stage, without unduly affecting the overall performance
25 of the circuit.

SUMMARY OF THE INVENTION

A digital blanking circuit is presented which overcomes the problems described above, preventing noise
30 that occurs following a digital signal transition from being propagated to a following stage.

The digital blanking circuit operates by allowing a

TOP SECRET//EYESOLE/460

first transition of a digital input signal to be passed on to a following stage, but prohibits the passing of subsequent transitions for a predetermined blanking interval. One embodiment of the present invention
5 employs a rising edge latch and a falling edge latch, the inputs of which receive the digital input signal and the outputs of which are connected to a two-to-one multiplexer. The output of the multiplexer is connected to a blanking interval circuit, which is triggered to
10 begin timing a blanking interval by a multiplexer output transition. The blanking interval circuit provides outputs which control the latches and selects the latch output to be transferred to the multiplexer output such that the multiplexer output (which serves as the blanking circuit output) is prevented from transitioning during a
15 blanking interval.

An "adaptive" blanking circuit is also described in which the digital blanking circuit is connected to the output of the last circuit in the signal path through which the digital input signal propagates. The blanking interval is terminated when the transition which triggered the start of the timing interval propagates through the entire signal path. In this way, the blanking interval is automatically adjusted to be the
25 same as the signal path delay.

Further features and advantages of the invention will be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings.

30

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating the basic principles of the invention.

35

FIG. 2 is a block diagram of one embodiment of a digital blanking circuit per the present invention.

FIG. 3 is an exemplary timing diagram for the digital blanking circuit of FIG. 2.

FIG. 4 is a diagram of another embodiment of a digital blanking circuit per the present invention.

5 FIG. 5 is an exemplary timing diagram for the digital blanking circuit of FIG. 4.

FIG. 6 is a block diagram of an embodiment of a digital blanking circuit which includes an adaptive latch.

10 FIG. 7 is an exemplary timing diagram for the digital blanking circuit of FIG. 6.

FIG. 8 is a block diagram of an adaptive digital blanking circuit as it might be employed in an overall system.

15 DETAILED DESCRIPTION OF THE INVENTION

The basic principles of a digital blanking circuit in accordance with the present invention are illustrated in FIG. 1. A digital input signal 10, which may exhibit noise 12 after a low-to-high or high-to-low transition, is produced by circuitry 14 such as a comparator. Signal 10 is used to affect the actions of a following circuit 16, which may behave erratically in the presence of noise 12.

25 To prevent noise from reaching following circuit 16, a digital blanking circuit 18 is interposed between the digital input signal source 14 and following circuit 16; the circuit receives digital input signal 10 at an input 24 and produces an output 26 to following circuit 16.

30 Digital blanking circuit 18 includes a blanking interval circuit 22, which is triggered to begin timing a predetermined "blanking interval" upon the occurrence of a transition of digital input signal 10. The digital blanking circuit is arranged such that its output 26 is prevented from transitioning during a blanking interval,

TOKUYO SHOBOGO

and tracks the digital input signal otherwise - i.e., when outside of a blanking interval.

The operation of digital blanking circuit 18 is shown in the FIG. 1 timing diagram. When a transition 28 occurs on digital input signal 10, it is passed on to output 26, and a blanking interval (B.I.) 30 of a predetermined duration is triggered. Transition 28 occurs immediately prior to blanking interval 30 (and thus outside of a blanking interval); therefore, output 26 is tracking input 10 when transition 28 occurs, and thus transition 28 is passed on to output 26. During the pendency of blanking interval 30, output 26 is prevented from re-transitioning. Thus, the transitions 32 that occur after initial transition 28, but during blanking interval 30, are prevented from appearing at output 26. In this way, digital blanking circuit 18 filters out noise and other undesired transitions which might otherwise cause erratic behavior in following circuit 16.

Blanking interval circuit 22 can be arranged to provide a blanking interval having one duration for a low-to-high transition of input signal 10 (i.e., for a "rising edge"), and a second duration for a high-to-low transition ("falling edge"), with the two durations being equal or different as desired.

Alternatively, digital blanking circuit 18 can include an "adaptive input" 34, which enables a blanking interval to be adjusted for the propagation delay of a signal path followed by digital input signal 10. For example, in FIG. 1, a signal path for digital input signal 10 might consist of digital blanking circuit 18 and following circuit 16, with the following circuit producing an output 36 which varies with the output 26 of digital blanking circuit 18 (and thus with digital input signal 10). Adaptive input 34 is connected to following circuit output 36. Blanking interval circuit 22 is

arranged to trigger the start of a blanking interval in the manner described above, but to terminate the blanking interval only when the signal applied to adaptive input 34 changes state - which does not occur until the
5 transition which triggered the currently-running blanking interval propagates to output 36. In this way, the blanking interval is automatically adjusted to be the same as the signal path delay. Blanking interval circuit 22 can be arranged to terminate the blanking interval
10 upon receipt of a rising edge, a falling edge, or either a rising or a falling edge at adaptive input 34.

The proper duration of the blanking interval is application-specific. For example, many following circuits specify a minimum width for pulses they receive as inputs. Setting the duration of the blanking interval to this minimum width ensures that the specification is met. Attention should also be paid to how long noise persists after a transition, to ensure that the blanking interval has a duration sufficient to prevent any of the
15 noise from being propagated.
20

For proper operation, the time lag between the blanking interval circuit's receipt of a digital input signal transition and the start of a blanking interval should be shorter than the bandwidth of the digital input
25 signal transitions. That is, the blanking interval circuit must be fast enough to trigger a blanking interval between the first and second transitions of digital input signal 10 when it is toggling at its maximum frequency, so that only the first transition is permitted to propagate to a following circuit.
30

One embodiment of digital blanking circuit 18 is shown in FIG. 2. Along with blanking interval (B.I.) circuit 22, digital blanking circuit 18 includes a falling edge latch 50, a rising edge latch 52, and a two-to-one multiplexer 54. Falling edge latch 50 has an
35

input 56, an output 58, and a LATCH input 60; a "0" is latched when LATCH is high, while output 58 tracks input 56 when LATCH is low. Rising edge latch 52 has an input 62, an output 64, and a LATCH input 66; a "1" is latched when LATCH is low, and output 64 tracks input 62 when LATCH is high. Latch inputs 56 and 62 are each connected to digital blanking circuit input 24 and receive digital input signal 10. Multiplexer 54 has inputs A and B, an output (26, which serves as the output of the digital blanking circuit), and a SELECT input; input A is passed on to mux output 26 when SELECT is high, and input B is passed on to output 26 when SELECT is low. Multiplexer output 26, labeled FILTERED OUTPUT in FIG. 2, would normally be connected to a following stage (not shown).

Blanking interval circuit 22 is connected to receive the output 26 of multiplexer 54 at an input 70, and to produce a SELECT signal 72 which is connected to the LATCH and LATCH inputs 60 and 66, and to the SELECT input of multiplexer 54.

The operation of the digital blanking circuit of FIG. 2 is illustrated with reference to the timing diagram in FIG. 3. Digital input signal 10 includes noise 12 which occurs after either high-to-low or low-to-high transitions. Initially, SELECT signal 72 is high, so that falling edge latch 50 is enabled to latch the next occurrence of a "0", the output 64 of rising edge latch 52 tracks its input 62, and multiplexer 54 passes input A, i.e., the output 58 of falling edge latch 50, to its output 26. Thus, when a high-to-low transition 73 occurs on signal 10, it is latched by falling edge latch 50, with falling edge 73 and the latched "0" passed on to output 26 via multiplexer 54.

As long as SELECT remains high, multiplexer output 26 and FILTERED OUTPUT will remain low, and thus the

noise 12 present on signal 10 after transition 73 is prevented from propagating to a following stage. The amount of time that SELECT remains high after the occurrence of transition 73 is the blanking interval, 5 which is established by blanking interval circuit 22. A transition at its input 70 triggers blanking interval circuit 22 to begin timing a blanking interval.

At the expiration of the blanking interval, blanking interval circuit 22 toggles the SELECT signal low. This 10 enables rising edge latch 52 to latch a "1" on the next low-to-high transition of digital input signal 10, and causes multiplexer 54 to pass rising edge latch output 64 to the FILTERED OUTPUT. When the latched "1" is received by blanking interval circuit 22, it triggers a new 15 blanking interval. Output 64 remains selected during the blanking interval, thereby keeping the noise 12 present on signal 10 after its low-to-high transition from propagating to a following stage. In this way, the noise found on digital input signal 10 after either a low-to- 20 high or a high-to-low transition is prevented from being propagated to following stages.

An advantage of the FIG. 2 arrangement is that the latching is done locally within the rising and falling edge latches themselves, providing very high speed edge 25 latching which does not depend on the response time of the multiplexer or blanking interval circuit. Also, signal propagation through the digital blanking circuit is kept relatively short; the signal path includes one gate (for a typical latch implementation as is shown in FIG. 4, below) and one multiplexer which is already "pre-selected"; i.e., with the appropriate latch output selected by the multiplexer before the occurrence of a transition. This pre-selection is an inherent 30 consequence of the circuit arrangement, in which the multiplexer alternately selects the outputs of the 35

falling and rising edge latches as digital input signal 10 toggles low and high.

Blanking interval circuit 22 can be arranged to provide blanking intervals of equal duration for either 5 rising or falling edges, or can be arranged to provide blanking intervals of different durations for rising and falling edges. To attain a filtered output of the type depicted in FIG. 3, the blanking intervals must last at least as long as the noise that follows a transition. 10 For example, if a particular digital input signal exhibits noise having an amplitude sufficient to be misinterpreted by a following stage for 2 ms following a high-to-low transition, and for 5 ms following a low-to-high transition, blanking interval circuit 22 should be 15 arranged to provide blanking intervals of at least 2 ms and 5 ms, respectively (if blanking intervals of different durations are possible), or at least 5 ms (if only one blanking interval is possible).

Blanking interval circuit 22 may be implemented with 20 a wide variety of different circuits. One possible implementation is simply a delay circuit which provides a delay from its input to its output. This could be accomplished with, for example, an R-C low pass filter. Adding inverters to buffer the filter's input and output 25 would improve circuit performance, as would adding voltage hysteresis to improve the delay circuit's noise immunity. A series of inverters connected in series might also be used to provide a desired delay.

Note that the digital blanking circuit configuration 30 shown in FIG. 2 is merely exemplary. For example, the LATCH and LATCH inputs of falling and rising edge latches 50 and 52 need not be complementary; the latches can be arranged to require signals of the same polarity to initiate a latch. As only one of the latches is to be 35 enabled at any one time, this would require the addition

of an inverter on one of the latch inputs, or for complementary control signals to be produced by blanking interval circuit 22. Circuit 22 might even be arranged to provide separate, coordinated control signals to the
5 LATCH, LATCH, and SELECT inputs.

As shown in FIG. 4, latches 50 and 52 are suitably implemented as SR latches, with the "set" (S) input of latch 50 and the "reset" (R) input of latch 52 connected to latch inputs 56 and 62, respectively, and the "reset"
10 (R) input of latch 50 and the "set" (S) input of latch 52 serving as the LATCH and LATCH inputs 60 and 66, respectively. Falling edge latch 50 is made from two cross-coupled NAND gates G1 and G2, and rising edge latch 52 is made from two cross-coupled NOR gates G3 and G4.
15 Each latch is inverting, such that the waveforms for outputs 58 and 64 (connected to MUX inputs A and B, respectively) are the inverse of those shown in FIG. 3; this is seen in the corresponding timing diagram shown in FIG. 5. Because the latches are inverting, an inverter
20 74 is connected to the output 26 of mux 54 to provide a FILTERED OUTPUT signal 78 of the proper polarity.

Note that the implementations of latches 50 and 52 shown in FIG. 4 are merely exemplary; many other possible circuits may be used to provide the latching functions
25 required by the invention.

One possible embodiment of a digital blanking circuit which includes an adaptive input as described above is shown in FIG. 6. Here, the FILTERED OUTPUT 26 is only allowed to re-transition after the transition
30 which triggered a blanking interval has propagated through a predefined signal path, which includes a following stage or stages (not shown) that toggle an output node in response to the propagating signal 10 transition. This results from automatically adjusting
35 the blanking interval to have the same duration as the

signal path delay. One way in which this may be accomplished is with the addition of an adaptive latch 100. Adaptive latch 100 has an input 102, which is connected to the output node at the end of the predefined signal path, an output 104, and a reset input 105. The digital blanking circuit can be arranged to be adaptive "on a falling edge", in which the blanking interval is not allowed to terminate until the occurrence of a high-to-low transition at adaptive input 102, "on a rising edge" (low-to-high transition at input 102 terminates blanking interval), or on either ("dual edge adaptive").

A blanking interval circuit 106 receives output 26 from multiplexer 54 and output 104 from adaptive latch 100 as inputs, and provides a SELECT signal 108 to latches 50, 52 and mux 54 in response. Blanking interval circuit 106 functions somewhat differently than was described in relation to FIG. 2. A blanking interval is still triggered by an appropriate transition on output 26 from multiplexer 54. Now, however, the termination of the blanking interval depends on the digital blanking circuit's configuration. If adaptive on a falling edge, adaptive latch 100 is arranged to latch a "0" upon receipt of a high-to-low transition at its input 102, and to toggle its output 104 to blanking interval circuit 106. In response, blanking interval circuit 106 terminates the blanking interval immediately thereafter. Note that, with the digital blanking circuit adaptive on a falling edge, a blanking interval triggered by a rising edge on digital input signal 10 is terminated in the conventional manner - after a predetermined time period.

Similarly, if the digital blanking circuit is adaptive on a rising edge, adaptive latch 100 latches a "1" and toggles its output 104 upon receipt of a low-to-high transition at its input 102, and blanking interval circuit 106 terminates the blanking interval immediately

TOP SECRET//EYES ONLY

thereafter. If adaptive on either edge, adaptive latch 100 toggles its output 104 upon receipt of either a high-to-low or low-to-high transition, so that the blanking interval is immediately terminated upon the occurrence of
5 either edge. The reset input 105 of adaptive latch 100 is preferably connected to SELECT signal 108, with latch 100 arranged to be reset from its latch mode when SELECT changes state.

A timing diagram depicting the operation of the
10 circuit of FIG. 6, as configured to be adaptive on a falling edge, is shown in FIG. 7. Falling and rising edge latches 50 and 52 and multiplexer 54 operate as in FIG. 2: with the SELECT signal initially high, falling edge latch 50 will latch the next occurrence of a "0",
15 the output of rising edge latch 52 tracks its input, and multiplexer 54 passes input A to its output 68. Thus, when signal 10 transitions from high-to-low, it is latched by falling edge latch 50, and the falling edge and the latched "0" are passed to output 26 via multiplexer 54.
20

As long as SELECT remains high, FILTERED OUTPUT will remain low, and thus the noise 12 present on signal 10 after its high-to-low transition is prevented from propagating to a following stage. Because the digital
25 blanking circuit is adaptive on a falling edge, the SELECT signal will remain high until the falling edge propagates through the predefined signal path and is latched by adaptive latch 100, which causes blanking interval circuit 106 to pull the SELECT signal low,
30 thereby ending the currently-running blanking interval.

The use of adaptive latch 100 also prevents noise present on adaptive input 102 from becoming troublesome. Because the adaptive latch latches on a high-to-low transition, noise that follows the transition is
35 prevented from being passed on to blanking interval

circuit 106.

With SELECT now low, the next low-to-high transition of digital input signal 10 causes rising edge latch 52 to latch a "1", which is propagated to FILTERED OUTPUT via
5 multiplexer 54. This is detected by blanking interval circuit 106, which, because the digital blanking circuit
is adaptive only on falling edges, begins timing a
blanking interval. Depending on the duration of the
blanking interval, it is possible that the digital input
10 signal will propagate to the end of the signal path and
through adaptive latch 100 before the blanking interval
expires. Blanking interval circuit 106 is arranged to
ignore this, however, and thus to keep SELECT low until
the expiration of the blanking interval. When this
15 occurs, SELECT goes high and the digital blanking circuit
is again prepared to receive a falling edge.

As noted above, digital blanking circuit 18 can also
be configured to be adaptive on a rising edge, or on
either a rising or falling edge, as required by a
20 particular application.

As a safety feature, blanking interval circuit 106
can include a timer which is triggered by falling edges
(if adaptive on a falling edge) and which times out after
a predetermined time period. Normally, for a falling
25 edge, the blanking interval is terminated via the output
104 of the adaptive latch. However, if the adaptive
latch never latches - because the adaptive input never
toggled, for example - blanking interval circuit 106 is
arranged to terminate the blanking interval when the
30 timer times out.

An additional timer might also be connected in
series with adaptive input 102. This additional timer
can be used to extend the adaptive blanking period to
cover any final stage settling or noise that might be
35 present.

TOP SECRET - CRYPTOGRAPHIC

Another possible adaptive embodiment of a digital blanking circuit 18 in accordance with the present invention is shown in FIG. 8, which depicts digital blanking circuit 18 in the context of an overall system.

- 5 As in FIG. 1, signal source 14 produces digital input signal 10, which is used by a following stage 16 to produce an output 120; in this example, output 120 is the output node at the end of a signal path taken by signal 10. This embodiment does away with the need for an
10 adaptive latch by incorporating the propagation delay through following stage 16 into the digital blanking circuit. That is, rather than connect the input 70 of blanking interval circuit 22 to the output 26 of multiplexer 54, it is connected to the end of the signal path - i.e., to output 120.
15

This configuration makes the digital blanking circuit inherently adaptive, in that blanking interval circuit 22 can take no action until a transition occurs at its input 70, which cannot occur until the transition has propagated through the entire signal path. By making the delays through the following stage part of the digital blanking circuit, the delays introduced by blanking interval circuit 22 - which would otherwise be chosen to mimic the system delays - can be made very
20 short, or even eliminated altogether. Note that, though following stage 16 in FIG. 8 is shown as a single stage, the signal path for digital input 10 can, in fact, include a number of stages.
25

While particular embodiments of the invention have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.

TOP SECRET//NOFORN